Decentralization and Deforestation: The Moderating Role of Polycentric Governance

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Abstract

Scholars and practitioners have long debated the merits of decentralization in the area of environmental policy. Here, we present new evidence regarding (a) the effects of decentralization on forest cover change, and (b) the conditions under which decentralization is likely to lead to better outcomes. Drawing on polycentric governance theory we build an argument about the institutional conditions under which decentralization will yield positive outcomes for common pool resource governance. We argue that local governments will be best equipped to address problems of deforestation when they are connected to and supported by other policy actors, including community organizations, national governments, and NGOs. We test this argument using multivariate matching and regression techniques employing a unique dataset on local forest governance and forest condition indicators in Peruvian and Bolivian municipalities. Three results challenge conventional wisdom. First, decentralization has an ambiguous effect on forest cover change. Second, polycentric governance arrangements are no more common in decentralized than in centralized regimes. And third, polycentric governance does have a stronger, positive effect on forest conservation in decentralized settings.

Key words: Bolivia, Peru, Decentralization, Natural Resources, Environmental Policy, Forestry, Governance

Decentralization and Deforestation

Introduction

Scholars have long argued about the environmental effects of decentralization. Some claim that decentralization reforms, especially in developing-country settings, have the potential to promote environmental degradation, while others argue that decentralization can promote better environmental outcomes (Agrawal and Ribot 1999; Faguet 2004; 2009; Faguet and Sanchez 2008; Ferejohn and Weingast 1997; Treisman 2007; Veron et al. 2006). Empirical evidence has been mixed, and there is no consensus regarding the effects of decentralization (Faguet 2004; 2009; Treisman 2007). Despite this lack of consensus, however, advocates and policy-makers have encouraged decentralization reforms, particularly in the developing world, as a solution to growing environmental problems (Ribot 2008; 2002; World Resources Institute 2005).

Here, we seek to bring some clarity to the debate on the effects of decentralization on environmental outcomes. We take a nuanced view of decentralization, arguing that it is unlikely that decentralization reforms will have uniformly positive or negative effects. Instead, the results of decentralization are likely to depend on other contextual factors. In particular, we focus on the nature of informal links between local governments and other actors, such as NGOs, community organizations, and central governments. We examine the effect of these links—"polycentric" governance involving many actors at multiple levels—and decentralization on forest cover change. We argue that decentralization is unlikely to have any statistically significant effect on forest cover change in and of itself. Where "decentralization" is used as an excuse for central governments to shirk responsibility and hand off the authority for forestry policy to poorly-supported local governments, the effects of decentralization are likely to be negligible or negative. On the other hand, where local governments are adequately supported by other actors, decentralization is likely to have a positive impact.

To test these theoretical ideas, drawn from the work of Ostrom and others (Andersson and Ostrom 2008), we use multivariate matching techniques, regression techniques, and a longitudinal dataset of municipal environmental governance and forest cover in approximately 200 Bolivian and Peruvian municipalities. The rationale for choosing these two countries is that while these neighboring countries share many important social, economic, and historical characteristics of human-forest interactions, they have adopted different approaches to forest governance. Peru remains to this day a highly centralized regime for forest decision making while Bolivia started to decentralize their governance structures in the mid-1990s.

We test the effect of decentralization on rates of forest cover change by simulating a natural experiment. Using Mahalanobis and propensity score matching models, we compare municipalities in a decentralized regime (Bolivia) to municipalities which share similar demographic and biophysical characteristics in a centralized regime (Peru). Finding no consistent effect of decentralization on either forest cover change or polycentric governance, we expand our analysis using Generalized Estimating Equation (GEE) regression techniques to determine if polycentric governance—governance by multiple actors—has different effects in decentralized and centralized municipalities. We find that municipalities in the decentralized setting (Bolivia) tend to experience lower rates of deforestation than municipalities in the centralized setting (Peru), but only where polycentricity is high; that is, only where municipal governments are supported by other actors. We also find some evidence of reverse causality in the relationship between polycentricity and forest cover change. We address this problem using instrumental variable regression (two stage least squares).

The rest of the paper is structured as follows. We start by summarizing the main findings of existing studies on decentralized forest governance. We emphasize a general trend in the literature to move away from a pure dichotomous framing of decentralization vs. centralization and to appreciate the benefits of establishing multilevel governance arrangements. This lesson prompts us, in the third section, to formulate an argument liking decentralization, polycentricity, and forest cover change. The fourth section describes the context in which we seek to test the argument (municipal governments in Peru and Bolivia), section five describes our data and methods, and section six presents the results. We end the paper in section seven with a discussion of what the results mean for future research and forest policy in developing countries.

Decentralization and Natural Resource Governance

Scholars have long debated the environmental effects of decentralization. Some claim that decentralization reforms will cause environmental degradation as a result of elite capture, by delegating authority to local governments which lack the capacity to carry out the tasks they are assigned, or by provoking a "race to the bottom". Others argue that decentralization will promote desirable environmental outcomes because local governments are more accountable to voters than national governments, because they can more easily gather information about local conditions and preferences, because decentralized governance permits experimentation and policy innovation, and because they are forced to compete against one another in providing services, leading to a beneficial "race to the top" (Agrawal and Ribot 1999; Faguet 2004; 2009; Faguet and Sanchez 2008; Ferejohn and Weingast 1997; Treisman 2007; Veron et al. 2006).

Empirical studies assessing these claims have generated contradictory evidence (Faguet 2004; 2009; Treisman 2007), but most recent empirical studies on forest governance and decentralization in developing countries have found decentralization to have a positive effect on forest condition outcomes. For example, Somananthan et Al. (2009) find that decentralization is associated with forest conservation in the Indian Himalayas. The authors make a controlled comparison between forests controlled by village councils and state-controlled forests and find that forests have been conserved at least as well and possibly better under decentralized management and at much lower cost. Also in the Indian Himalayas, Baland et Al. (2010) find that local governance of forest resources generally outperforms central government management in a variety of forests areas. Likewise, in a comparative analysis of data from 163 forests in 13 countries, Hayes (2006) seeks to determine whether legally established protected areas perform better that local user-governed forest areas. The author finds higher levels of overall vegetation density in community-controlled areas.

These findings are consistent with a recent meta-analysis of 73 published case studies on centralized and decentralized forest conservation approaches in a wide variety of contexts (Porter-Bolland et al., forthcoming). The authors find that decentralized conservation approaches generally yield more stable forest cover. Based on these results, they call for further research to identify the causes of the differing outcomes between centralized and decentralized natural resource management. This paper responds directly to this challenge.

Here, we seek to address four important limitations of the extant literature on decentralized natural resource governance. First, while some studies analyze how local variations in institutional arrangements affect the performance of decentralized regimes, (i.e. Crook & Manor, 1998; Pacheco, 2000; Larson, 2002; Agrawal & Ribot, 1999) most are constrained in their generalizability in that they often focus on a very small sample of local units within a single geographic region. While such qualitative studies are valuable, they are less likely to generate generalizable findings on the broader effects of decentralization. Second, the studies that do analyze large-n samples of decentralized and centralized resource units tend to focus on community-level resource user groups as the unit of analysis and not local general-purpose governments (i.e. municipal governments; the most common target of decentralization reforms). Third, few comparative decentralization studies test the causal processes that might drive variations in performance. Fourth, longitudinal data on local government units in decentralized or centralized regimes is rare. Finally, very few studies examine actual biophysical outcomes on resources (such as forest cover change—our key outcome variable here). Instead, most focus on policy outcomes and human activity. By addressing these four issues, we hope to contribute to more reliable evidence concerning the environmental effects of decentralization as well as the conditions under which it is most effective in protecting the resource.

Our Theoretical Approach

Policy reforms, such as decentralization, do not automatically translate into environmental outcomes. It is therefore crucial to analyze the processes in the middle of a causal chain linking policies with outcomes. We argue that the effects of a policy change depend especially on the role played by local institutional arrangements in incentivizing local governance actors—local politicians in particular—to pursue particular policies.

Our approach builds on the work of the new institutionalism school of political economy (North 1990, Ostrom, 1990; Knight 1992, Horn 1995, Bates 1998). We emphasize the value of considering institutions at multiple levels, drawing on earlier work that analyzes institutions as "two-level games" (Putnam 1994), "nested action arenas" (Ostrom 2005), or systems of "multi-level governance" (Hooghe & Marx 2003). We recognize that institutional arrangements are nearly always made up of several layers of social orders—from local micro-interactional orders to international and transnational arrangements—and that the relationships of complementarity and contradiction between these layers are crucial.

We use these insights to build a model for the analysis of decentralized resource governance. Through this approach, we highlight the ways in which decentralization reforms are *filtered* by institutional arrangements to produce outcomes visible on the landscape. The key point in our approach is that the configuration of local institutional arrangements shapes the extent to which decentralization affects the environment. Specifically, we hypothesize that the degree to which local governance systems are connected to actors at different levels of governance will help determine the environmental effect of decentralization reforms. The rationale for this hypothesis is that, to be able to control powerful economic and political drivers of deforestation, under-funded and under-staffed local government administrations are unlikely to be successful on their own. They need to draw on contributions from other, external governance actors in order to be effective (Andersson, 2004; Bray et al 2010; Andersson and Ostrom, 2008). While a number of scholarly works have posited this kind of relationship (Andersson and E. Ostrom 2008; E. Ostrom, Schroeder, and Wynne n.d.; V. Ostrom and E. Ostrom 1999), there has been little testing of these ideas, especially with quantitative data.

Data and Methods

To test the study's main hypotheses, we rely on a comparative research design and longitudinal survey data from 200 selected municipalities in Peru and Bolivia at two periods in time, as well as satellite imagery of forest cover.

We focus on local governments in Bolivia and Peru for a number of reasons. While these neighboring countries share a number of essential biophysical, socio-economic, historical and cultural characteristics, they differ on the variable of theoretical interest to this study: decentralization. Starting in 1996, Bolivian local governments were given substantial rights, responsibilities and resources from the central government to govern forest areas within their territories, while Peruvian local governments have no formal mandate to for forest governance (Andersson and Van Laerhoven 2007; Andersson, Gibson, and Lehoucq 2006; Kauneckis and Andersson 2009).

Data

There are four major data sources for this study: (1) surveys of local governance actors (2000 and 2007), (2) census/archive data (2000, 2007), (3) satellite images (1993, 2000, and 2007), and (4) digital elevation models of Peru and Bolivia. In each of the 200 selected municipalities, we interviewed the elected mayor in two waves: 2000/1 and again in 2007/8. In addition, we interviewed municipal forestry officials and community leaders in order to triangulate responses in 2007/8. Each face-to-face interview took approximately 1.5-2 hours. The survey instrument (258 questions) was designed to elicit information regarding the interviewee's policy priorities, staff, relationship with central and nongovernmental agencies, and relationship with citizens. It uses a variety of techniques to understand political incentives and behaviors. We checked several interview responses with archival data and found the survey instrument to be highly reliable. We also use government statistics from both countries for some of our key variables (as noted below).

Our biophysical data was generated from two sources: (1) digital elevation models to create topographic data, and (2) forest cover data that were generated using remote sensing techniques

(Landsat TM imagery). We use digital elevation models to generate estimates of altitude and the percentage of land in each municipality above a 12% grade—that is, the slope above which commercial, large-scale agricultural production is not feasible. We also hired remote sensing analysts in Peru and Bolivia to estimate forest cover change for our sample of 100 local government territories in each country. This work is still underway and here we include the analysis of data from 100 local government territories in Bolivia for the period 1993-2008, and for 35 Peruvian municipalities in the period 1990-2008. Table 1 below presents the descriptive statistics of the main variables included in the empirical analysis.

[Table 1 about here]

There are two independent variables of particular interest. We are interested in the effects of *de jure* decentralization reforms and degree of polycentricity on forest cover change (deforestation) over time. De jure decentralization is a dummy variable that identifies whether the municipality was located in a formally decentralized regime, therefore, this variable is coded 0 in both time periods for Peru, and 0 in period 1 for Bolivia, and 1 in the second time point for Bolivia, as illustrated by the matrix below.

Polycentricity is an ordinal variable that denotes the degree to which a local government is connected through frequent interactions about forestry with three different governance actors: (1) Central government agents; (2) community-based organizations, and (3) NGOs. We constructed this variable in the following manner: We took three survey questions from our unique survey dataset of 200 Bolivian and Peruvian municipalities at two points in time (2000/2001 and 2007/2008) asking the frequency with which community organizations, central governments, and NGOs expressed opinions regarding forestry to municipal governments. Where these organizations expressed opinions "sometimes," "frequently" or "very frequently," they were assigned a 1, otherwise, the new variables were coded 0. These values were then added together to form an index of polycentricity. Theoretically, this approach is valid as a measure of the strength of local links with other governance actors. In particular, we are interested to see if strong links with multiple actors have an impact on governance under decentralization and in centralized settings. To confirm that our results are not the result of a single element of this index, we also test the effects of these measures individually. These results are outlined below.

We test the effects of these two variables—decentralization and polycentricity—and their possible interactive properties, on two measures of forest conditions: (1) annualized rate of total forest cover change, and (2) annualized rate of illegal deforestation. The latter variable was calculated by using GIS technology that overlaid maps of land cover change with land use prescription maps provided by the Bolivian national government, which allowed us to generate estimates of the annual amounts of deforestation that took place inside areas that were formally protected by national land use zoning laws.

Quantitative Estimation Techniques

Our empirical tests employ three multivariate techniques: (a) Mahalanobis matching with propensity scores, (b) GEE regression using Mahalanobis matching with propensity scores as a pre-processing technique to eliminate non-comparable observations, and (c) two stage least squares (also called instrumental variable regression). In the case of (b) and (c), we use matching as pre-processing to eliminate non-comparable observations.

We use multivariate matching techniques to examine the effects of decentralization. Specifically, we use a matched sample in which municipalities in a decentralized setting are matched with non-decentralized municipalities which share several key characteristics. The matching technique we used is called Mahalanobis matching and it matches observations (in this case, several treatment cases for each control) according to the “Mahalanobis distance” between them. The Mahalanobis distance is the distance between observations in a multi-dimensional space, in which each dimension is a control variable (a variable upon which the matching is to be based). By using this technique, it is possible to generate a set of matched cases in which treatment and control cases are not significantly different on observables, except for the treatment. In essence, then, the technique, like other matching techniques, generates a “treatment” and “control” group that are statistically no different on important observable control variables (Rubin 1980; Sekhon 2009)

Quantitative methodologists suggest that the use of a propensity score as a matching criterion is helpful in improving the “balance” of matched samples, such that “control” (centralized) cases are more comparable to “treatment” cases (Sekhon 2009; Smith 1997). We generate propensity scores—effectively, the likelihood that a municipality with the observed characteristics of a given sample municipality will appear in the treatment (decentralized) group—using several key biophysical variables, including annual rate of deforestation (lagged), the proportion of municipal area with a slope over 12% (the percent above which most mechanized agriculture is impossible), road density (km. per square km., logged), population, and municipal area (ha, logged). These propensity scores are then used as a matching variable in our Mahalanobis matching models, in addition to other control variables.

We use GEE (generalized estimating equation) models to address the autocorrelation problems inherent in the use of panel data in our regression models. This approach allows us to control for possible within-unit correlation (Frees, 2004; Rabe-Hesketh and Skrondal, 2008). Before running GEE regression models, we also eliminate non-comparable cases from our sample using matching, as a way of reducing the impact confounding factors in the analysis.

Mahalanobis matching with propensity scores (as above) is used in a screening, pre-analysis stage to select pairs of local governments (decentralized and centralized) that are as similar as possible before running the GEE regressions, as suggested by Ho, King and Stuart (2007).

Matching

Ideally, to test the effects of decentralization on forest-related outcomes such as deforestation, we would use a randomized, controlled experimental approach, in which decentralization reforms would be applied to randomly selected jurisdictions such as municipalities, while other jurisdictions would not receive the decentralization “treatment”. If decentralization were applied randomly to municipalities in Bolivia and/or Peru, for example, it would be possible to examine the effects of decentralization, by comparing the average changes in forest cover in decentralized municipalities to changes in forest cover in cases which have not been “treated“ with decentralization.

Such an approach is not available to many researchers, and although decentralization reforms in forest policy have been applied to municipalities in Bolivia and not in Peru, a simple comparison between Bolivian and Peruvian municipalities in terms of land cover change and other forestry-related outcomes (the so-called difference in difference approach) is not appropriate. This is because we are likely to confuse differences between Peru and Bolivia with the effects of decentralization (Fisher 1966; Rubin 1990; Splawa-Neyman 1990).

The most common matching approach used the social sciences is propensity score matching, which uses a two-stage approach. First, observations are assigned a value which represents the probability that that observation will be observed in the treatment group. These probabilities are estimated using a simple logit or probit model. Second, cases of similar propensities are matched, and cases with significantly differing controls are excluded from the sample (Sekhon

2009). However, since the treatment in our case, decentralization depends on the geographic location of each observation (within Bolivia or Peru), using conventional propensity score matching is not an option. Instead we employ an alternative approach, called Mahalanobis matching.

Although we recognize the importance of linear regression and its extensions, multivariate matching techniques enjoy a number of advantages over regression. First, because after the balancing process is complete, statistical tests are essentially nothing more than difference-of-means tests, matching approaches do not assume a linear, additive effect, unlike OLS and its variants. This is an advantage if OLS assumptions of linear additivity are not correct. Second, because cases out of the area of common support are excluded—that is, cases where control variable values are not comparable between control and treatment cases are excluded—extreme values of control variables cannot drive spurious results. In effect, matching tests compare apples to apples, not apples to oranges (Brady and Mcnulty 2011; Heinrich and Lopez 2009).

At the same time, there is a downside to relying exclusively on matching techniques in policy analysis. Matching is not useful when examining the interactive effects of multiple inputs on a single outcome. To deal with this shortcoming, as noted above, we use regression (GEE) models to test hypotheses involving interactions between polycentricity and decentralization.

Two Stage Least Squares

As described below, the results of our GEE models lead us to suspect a degree of reverse causality in the relationship we detect between polycentricity and forest cover change. To address these issues, we use the standard technique—two stage least squares, also called instrumental variable regression—instrumenting for our possibly endogenous independent variable, polycentricity. Because these statistical models are presented in response to an endogeneity problem suggested by our GEE results, we present and discuss them in the discussion section, after we present our main results.

Results

The first set of empirical results we present here are those showing the effects of decentralization on deforestation and illegal deforestation.

First, we use logit regressions to generate propensity scores for our observations. Then we use Mahalanobis distance to match our sample for six control variables: forest cover in the previous period, percentage of land with a slope greater than 12%, road density (natural logarithm), total population (natural logarithm), municipal size in hectares (natural logarithm), and propensity score. Using a p-score caliper of .01 (that is, cases with p-scores differences greater than .01 are not matched), we find no statistically significant difference between matched decentralized cases (n = 111) and centralized cases (n = 48). However, where we widen the p-score caliper somewhat (to .05), our matched number of cases increases (treatment n = 123 and control n = 64), and we do show a positive relationship between decentralization and forest cover change. That is, deforestation—negative change—is lower, and afforestation—positive change—is greater, therefore decentralization is associated with a desirable effect on forest cover change. These differences between models, shown in table 2, may be related to the relatively low n of the first model (in which case the second model would be correct), or because we are comparing apples to oranges in the second model (in which case the first model would be correct), and there is no way to know which using our data. Therefore, the only reasonable conclusion we can draw from this analysis is that the impact of decentralization on forest cover change is ambiguous.

[Table 2 here]

Next, we conducted a series of tests to determine (a) whether polycentricity is more likely under decentralization (as many advocates have assumed) (Ribot 2008; 2002), and (b) whether polycentricity has a differing effect between centralized and decentralized regimes. Our results suggest that (a) contrary to the literature, strong polycentric governance is no more likely under decentralization, probably in part because decentralization is seen as an opportunity by central governments and other actors to disengage from underperforming municipal governments. However, we also find that where strong polycentric governance does exist under decentralization, it tends to be more effective.

To test the effect of decentralization on multilevel governance, we used this variable as a dependent variable in matching models similar to those described above. We also tested an additional set of models in which we replaced our "decentralization" variable with a new coding in this model, in which Peru is coded 0 in both time periods, and Bolivia is coded 1 in both time periods. This is because decentralization reforms took place in the mid-1990s and, although forest cover would not have responded to decentralization by 2000 (the time of our first Bolivian survey wave), we have seen qualitative evidence to suggest that policy changes had in fact been implemented in Bolivia by the time we interviewed local government actors in 2001.

Results were consistent: decentralization is associated with no difference in polycentricity. This result held also for using alternative codings of the polycentric governance variable, including a mean index of the raw values of the three survey questions, and additive indices using alternative cut points in the five-point survey questions, although we found alternative codings were more sensitive in matching (but not GEE) models. In table three, we present the results of one set of matching models (with a .01 p-score caliper and using our alternative coding for decentralization) but other models yielded similar results.

[Table 3 here]

We then tested the effects of polycentric governance on deforestation across decentralized and centralized municipalities to see if the effect differed. To do so, we generated a interaction term in which “decentralization” was interacted with “polycentricity” and included the interaction term, as well as both base terms, in a GEE model with the same control variables used above. Where an interaction term is included in a regression model like the GEE models used here, the significance of coefficients in the table is not substantively meaningful, therefore, as suggested by methodologists, we show a graph of the marginal effects of a change from a centralized to a decentralized regime, conditional on the level of polycentricity (Brambor, Clark, and Golder 2006) although we also show our regression results in table 4.

[Table 4 here]

The effect of decentralization on forest cover can be easily seen in figures 1 and 2. Figure 1 shows the marginal effects of decentralization on forest cover change across municipalities with varying degrees of polycentricity. Where polycentricity is weak (where only one of the community organizations, central government, or NGOs has frequent contact with municipal governments), there is no significant effect of deforestation. However, where polycentric governance is stronger, decentralization has a positive and significant effect on forest cover change, leading to lower rates of deforestation. Figure 2 shows the predicted values of forest cover change as they vary across decentralized and centralized regimes and different levels of polycentricity. This graphic shows the same data as that depicted in figure 1 but in a slightly different way. Here, rather than showing the predicted change in rates of forest cover change from a shift from centralized to decentralized governance, figure 2 shows the predicted rate of forest cover change. In both graphics, other variables are held at their median values.

[Figure 1 here]

[Figure 2 here]

We also break down our index of polycentricity into its component elements, interact each variable (NGO engagement, central government engagement, and community organization engagement with the municipal government) and test each of these variables independently, to see if some component of our index of polycentricity is driving our results. None of these variables, however show significant relationships, suggesting that it is *polycentricity*, not engagement with some particular type of organization, that is having an impact here.

Reverse Causality

Figure 1 shows that the relationship differs between polycentricity and annual rates of forest cover change in centralized and decentralized municipalities. In decentralized municipalities, greater polycentricity is associated with *lower* rates of deforestation, and *higher* rates of afforestation. On the other hand, in municipalities in centralized regimes, higher levels of polycentricity is associated with more undesirable outcomes—*higher* rates of deforestation, and *lower* rates of afforestation. The first of these relationships is of course consistent with our theory and hypothesis. However, the second relationship presents something of a puzzle, in that it seems unlikely that greater community, NGO, and central government engagement with municipal governments will cause greater deforestation. At worst, according to the hypothesis presented here, there should be no relationship between polycentricity in centralized regimes, or, more likely, polycentric governance will have some effect, but one which is weaker than that in decentralized settings.

The most likely explanation appears to be reverse causality. Specifically, it is likely that high rates of deforestation lead community organizations, central government agencies, and NGOs to become involved in forestry policy, leading to the negative correlation between polycentric governance and rates of forest cover change. In essence, higher rates of deforestation are probably leading to greater polycentricity, and not the other way around.

This presents an interesting problem. This type of reverse causality is also likely in decentralized settings, and may be even more likely, since NGOs, communities, and central government agencies are most likely to become involved in municipal-level forestry policy if municipal governments are seen as having some right to carry out forestry policy.

The standard approach to address this type of problem is two stage least squares regression, which requires the instrumentation of an independent variable with a third variable—the instrument—that has an effect on the dependent variable only through the endogenous independent variable of interest (Deaton 2009). Here, we use three variables as instruments for community organization engagement in forest policy and polycentricity. These are the number of community organizations involved in forest-related activity, the presence of a municipal forestry agency, the size of the municipal budget, and the local government's tendency to intervene in local disputes between actors regarding the forestry sector. We believe these variables are orthogonal to forest cover change (our dependent variable) and to the extent they impact forest cover change, they do so primarily through polycentric governance. Specifically, municipal budgets in both Peru and Bolivia are largely determined formulaically, by the central government, and distributed based on total population in jurisdiction, level of poverty, amount of forest land under logging concessions (Bolivia) and the presence of mineral wealth (Peru). Scholars examining the effect of these budgets on forest outcomes or policy have been unable to find any causal relationship (Killeen et al 2007; Kaimowitz et al 2001; Andersson and Gibson, 2007; Andersson, 2004). Municipal forestry agencies are imposed from above in Bolivia, and though may exist voluntarily in Peru, scholars have similarly been unable to find any relationship between the mere existence of municipal forestry agencies and deforestation rates (Forrester-Kibuga,and Samweli, 2010; Alvarez and Naughton-Treves, 2003). Instead, what contemporary research has shown is that the degree to which these variables influence forest condition outcomes depend on a series of political and socioeconomic factors, such as the local interests in agriculture or forestry land uses as well as the degree of economic dependence on forests among local inhabitants. Finally, although municipal governments' likelihood of intervening in local disputes is probably determined, in part, by local conditions, the tendency of local governments to intervene in general local disputes (of any type) is unlikely to be causally related to forestry outcomes, though it is well correlated with community organization demands for forestry and polycentric governance.

The use of instrumental variables is somewhat complex in our case, because of the presence of an interaction term in our models, and because we are using time-series data with a relatively large number of observations compared to the number of time periods. We test two models, one in which the independent variable is "community engagement in forestry" and the other in which the independent variable is "polycentricity." In our first stage, we regress "UFM" (municipal forestry agency), "municipal budget", and "conflict intervention" on the independent variable, using population-averaged (GEE) regression with unstructured correlation within-unit correlation assumption and an identity link function (which assumes normally distributed errors—an assumption which appears to be satisfied by our models). We then save the predicted values of this model and interact them with "decentralization" in our second stage model. The predicted values then replace "polycentricity" and "community engagement in forestry" in the second stage model as well.

Results of our two stage least squares models are as expected, as shown in figures 3 and 4 (marginal effects and predicted values). Although confidence intervals are somewhat wider than in the models presented above, we find that the relationship between polycentricity and forest cover change flattens out in centralized settings. However, the relationship between polycentricity and forest cover change is positive and significant, and predicted values are significantly different from those in centralized settings. For a graphic depiction, see figures 3 and 4. Here, as above, the differences between municipalities in centralized and decentralized settings are only significant where polycentricity and community engagement, respectively, are relatively strong. But in contrast to the relationships shown above, these models show no significant relationship between forest cover change and community engagement and polycentricity in centralized settings—a finding which is consistent with our predictions. These regression results are shown in table 5.

[Figure 3 here]

[Figure 4 here]

Discussion and Conclusions

The results presented here challenge three received wisdoms about the relationships between decentralization and deforestation. First, we find that this relationship is less clear-cut than what previous studies on forest decentralization has claimed. Decentralization's effect on forest conditions is not unequivocally positive, which so many recent empirical studies have found. Our analysis demonstrates that the correlation between decentralization and deforestation that appear as statistically significant in time-series, cross-sectional regression models loses its significance when more robust multivariate matching techniques are employed. It is possible that previous findings may rely on spurious correlations. It should be noted, however, that none of our four estimation techniques found a *negative* effect of decentralization on forest cover.

The fact that decentralization does not have a negative effect on forest conservation in this case is surprising for two reasons. First, macroeconomic and agricultural policies in Bolivia are more favorable to export-oriented agriculture than in Peru. As in other countries in the region, agricultural policies have been known to be an important driver of deforestation. For example, in Brazil, state-sponsored incentives for cattle ranching implemented in the 1980s resulted in the conversion of forest to pasture in the Brazilian Amazon at an average rate of 35,000 km/year (Moran et al 1994). Agricultural credits expedited deforestation by offering easy credit to individuals establishing large ranches, allowing colonists in Rondonia, Brazil, to use state credit to purchase chainsaws (Binswanger, 1989). Without these macroeconomic subsidies, forest clearing activities would likely have been much lower, as deforestation rates declined after the removal of the incentives in 1987 (Moran et al 1994). Following this logic, we would expect deforestation to be higher in Bolivia than in Peru because the Bolivian government offers financial incentives in the form of export credits and duty-free exports on soy bean. Those instruments in combination with accessible private credit schemes has promoted a massive expansion of agroindustrial activities and deforestation, especially in the Department of Santa Cruz (Steininger et al 2001). The surprising thing is that but the data shows the exact opposite pattern: decentralized Bolivian municipalities are less likely to deforest than centralized Peruvian ones. In light of these conditions, it is unlikely that decentralization has had a negative effect on forest conservation in Bolivia.

The second reason the null finding is surprising is that Peru' Land use zoning laws are much more ambiguous and lenient than those in Bolivia. For this reason, one would also expect

Bolivia to have significantly more illegal deforestation than Peru, but this is not the case. Again, it seems safe to conclude that decentralization in Bolivia has not had a negative effect on illegal deforestation.

Decentralization has been viewed by some policy scholars as a way to encourage polycentricity. What we find is different: using our data, polycentricity is no more common in decentralized than in centralized settings.

That is not to say that multilevel governance is not important in decentralized regimes. On the contrary, we find that multilevel governance is particularly important in regimes that have a decentralized structure. Our interaction analysis shows that the marginal effect of decentralization on forest cover change increases as multilevel governance grows stronger. Hence, the effect decentralization has on the environment depends on the local institutional arrangements for polycentric governance. A practical implication of this findings is that the forest conservation performance of decentralized governance units may be enhanced by strengthening the institutional support network at multiple levels.

Future research in this area would benefit from both improvements in data availability. More complete forest covers change data is needed, including longer periods of time and more frequent intervals to the analysis. Adding more time would allow for introducing more realistic policy lags between policy implementation and observable effects on the landscape. Another data need is to create valid proxies for local market signals that influence land use allocation decisions. We hope to fill these gaps with future work.

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Table 1. Descriptive Statistics for all variables

Variable	Obs	Mean	Std. Dev.	Min.	Max.
Annual rate of forest cover change	249	0.004	0.159	-0.928	1
Forest cover lagged (pct.)	268	17.827	27.571	0	100
Pct. slope over 12%	465	46.317	31.777	0	94.8
Road density (km. per sq. km, natural logarithm)	249	-2.470	1.702	-9.210	0.473
Population (ln)	421	8.27	1.48	3.67	12.62
Municipal size (ha., logged)	465	11.080	1.616	7.183	15.792
Decentralization	472	.209	.407	0	1
Polycentricity	422	1.720	1.035	0	3
Polycentricity X decentralization	422	.365	.858	0	3
UFM	424	.202	.394	0	1
Budget size	426	1856.627	10306.27	0	184771.4
Conflict intervention	205	.512	.463	0	1

Table 2. Matching results: Decentralization's effect on forest cover change

Mahalanobis matching	N (treated)	N (control)	ATT	SE	ATE	T
.01 p-score caliper	49	107	.036	.032	.047	1.11
.05 p-score caliper	64	123	.081	.036	.066	2.20

Table 3: Matching results: Decentralization's effects on polycentricity

Model	N (treated)	N (control)	ATT	SE	ATE	T
Mahalanobis with .01 p-score caliper	48	111	-.295	.580	-.263	-.51

Table 4. GEE results: Polycentricity's differing effect across centralized and decentralized regimes. Note that methodologists suggest that regression tables like these are not helpful in the case of interaction models like ours (Brambor, Clark, and Golder 2006). Therefore, for a better idea of our results, see figures 1 and 2.

	Annual rate of forest cover change
Decentralization	0.011
	(0.742)
Polycentricity	-0.016
	(0.185)
Decentralization * Polycentricity	0.031
	(0.124)
Slope above 12% (pct.)	0.000
	(0.920)
Road density (ln)	-0.009
	(0.465)
Population (ln)	-0.015
	(0.003)**
Municipal size (ha., ln)	-0.002
	(0.847)
Forest cover (pct., lagged)	0.000
	(0.620)
Constant	-0.042
	(0.697)
Observations	156
Number of units	101
	p values in parentheses + significant at 10%; * significant at 5%; ** significant at 1%

Figure 1. The marginal effect of decentralization on forest cover change, conditional on polycentricity. The difference between centralized and decentralized municipalities is not significant where polycentric governance is weak, but the effect of decentralization is strong and significant where polycentric governance is stronger. Dashed lines represent 95% confidence intervals.

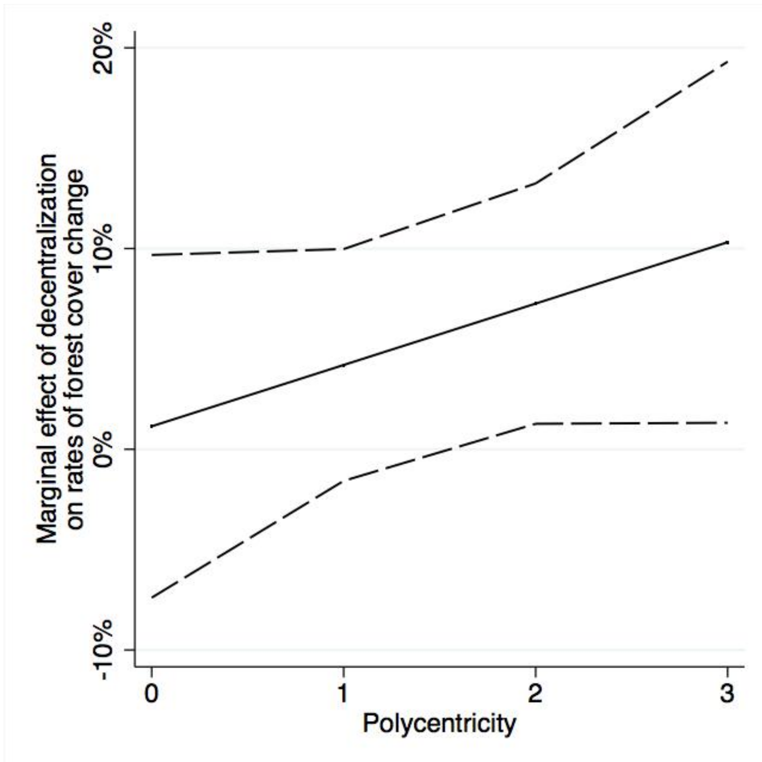

Figure 2. Predicted values of rates of forest cover change, conditional on polycentricity. Figure shows the predicted values that generate the marginal effects shown in figure 1.

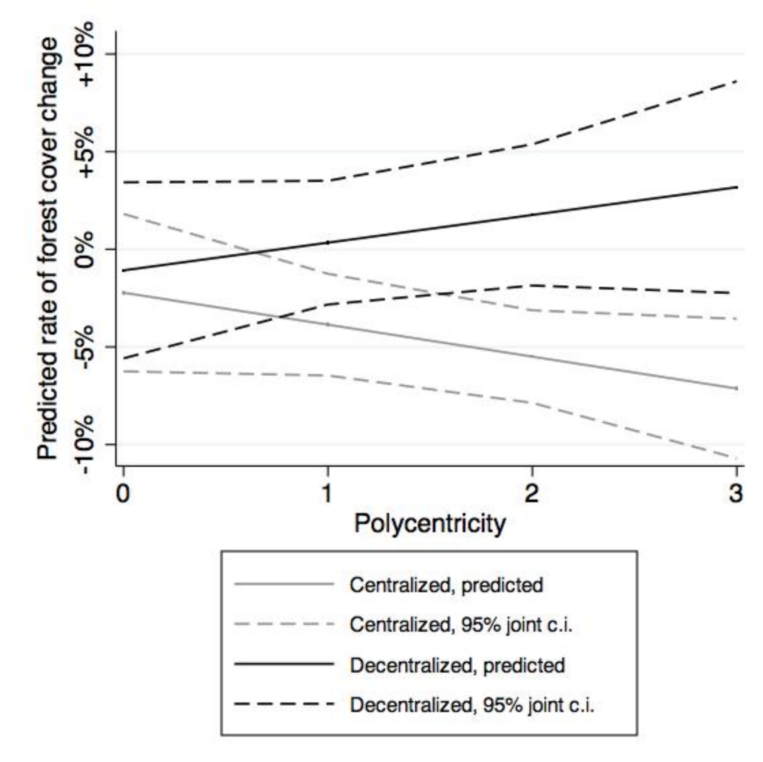

Figure 3. Marginal effects of decentralization, conditional on polycentricity, estimated with instrumental variable regression. Dashed lines represent 95% confidence intervals.

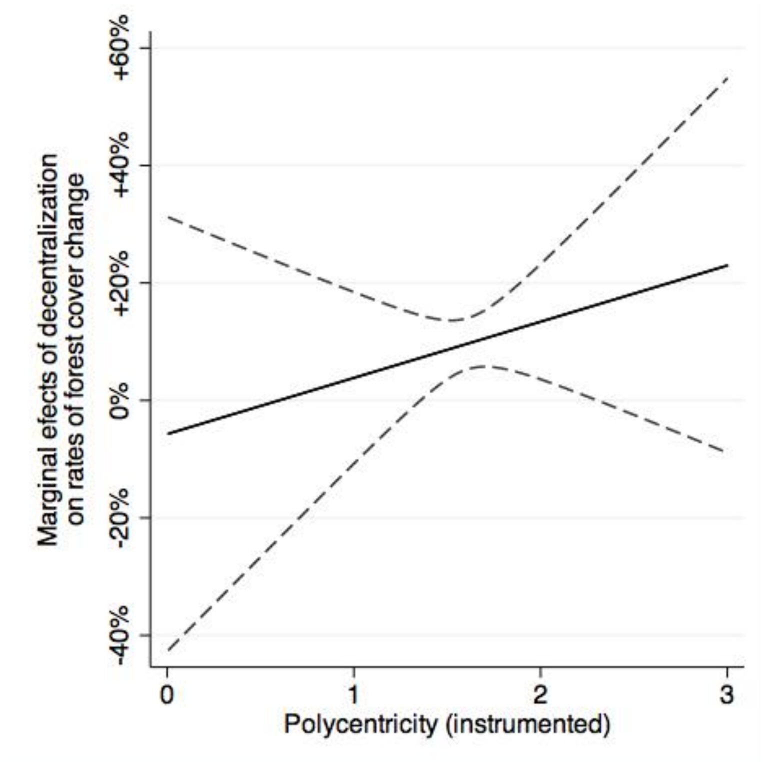

Figure 4. Predicted values of rates of forest cover change, conditional on polycentricity, instrumental variable regression results. Figure shows the predicted values that generate the marginal effects shown in figure 3.

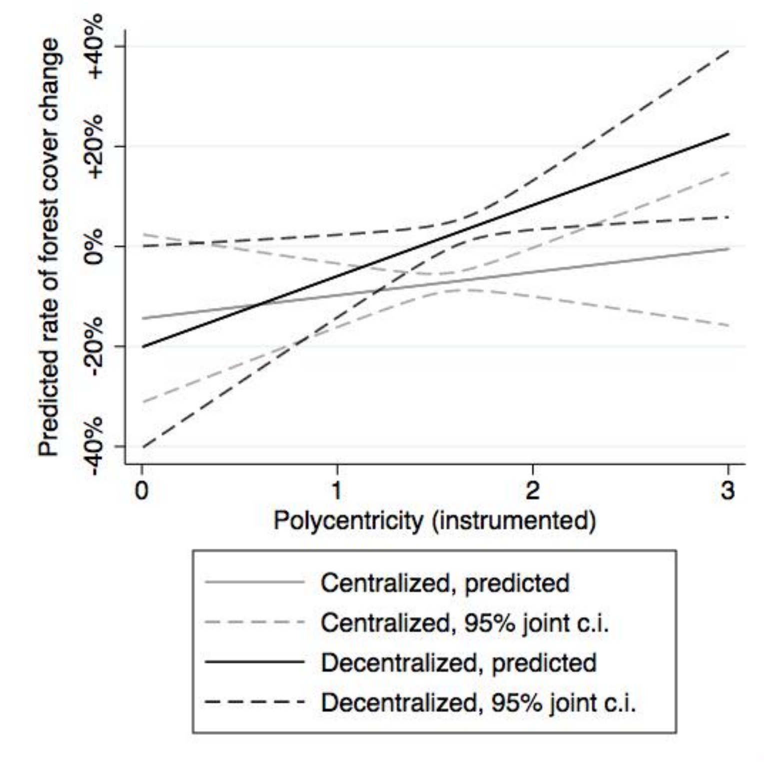

Table 5. Instrumental variable regression results: Polycentricity's differing effect across centralized and decentralized regimes. Note that methodologists suggest that regression tables like these are not helpful in the case of interaction models like ours (Brambor, Clark, and Golder 2006). Therefore, for a better idea of our results, see figures 3 and 4. These models are GEE (generalized estimating equation) regressions with identity link function and unstructured within-unit correlation assumption.

	First Stage	Second Stage
Conflict intervention	0.141	
	(0.592)	
UFM	0.393	
	(0.127)	
Budget (Thousands of $US)	-0.000	
	(0.756)	
Decentralization		-0.057
		(0.740)
Polycentricity		0.046
		(0.472)
Decentralization * Polycentricity		0.096
		(0.363)
Slope above 12% (pct.)		-0.000
		(0.039)*
Road density (ln)		-0.026
		(0.003)**
Population (ln)		-0.020
		(0.007)**
Municipal size (ha., ln)		0.016
		(0.017)*
Forest cover (pct., lagged)		-0.001
		(0.061)+
Constant	1.509	-0.183
	(0.000)***	(0.113)
Observations	101	103
Units	75	77

p values in parentheses
+ significant at 10%; * significant at 5%; ** significant at 1%; *** significant at .1%